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THE EFFECTS OF NOISE IN BLAST-RESISTANT SHELTERS

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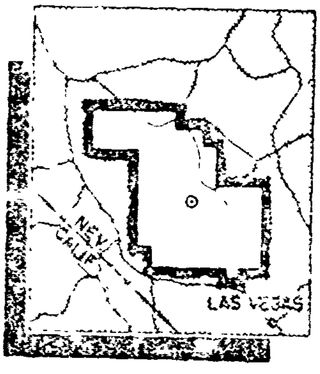

CIVIL EFFECTS TEST GROUP

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WT-1180

Report to the Test Director

THE EFFECTS OF NOISE IN BLAST-RESISTANT SHELTERS

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May 1956

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Robert L. Corsbie, Director, Civil Effects Test Group; Clayton S. White, Director of Research, Lovelace Foundation, and Director, Program 33; Howard W. Merideth, Lovelace Clinic; Roland S. Milican, Division Supervisor, Field Test Organization, Sandia Corporation; Luke J. Vortman, Sandia Corporation; Harold Birnbaum, Ammann and Whitney Company; Mrs. Isabell Benton, Lovelace Foundation; and Mrs. Betty B. Tatum, Sandia Corporation.

ABSTRACT

A fatigue syndrome has been observed to develop in animals that experience a nuclear explosion while confined in a blast-resistant shelter. In order to determine the importance of noise as a contributing factor, groups of deafened and nondeafened albino male rats were placed in blast-resistant shelters on two explosions of the Operation Teapot series. Noise measurements were made which showed that noise intensities reached a level as high as 181 db, but only for durations of 35 msec. No differences were found between the deafened and nondeafened rats in the postshot experimental tests. It was concluded that noise in this particular instance was not a parameter of importance in the etiology of fatigue.

Many of the animals received significant doses of ionizing radiation. This affected the learning performance of the untrained animals; however, it did not affect the retention of a learned response in the case of the animals that had been trained prior to the explosion. Despite the fact that these trained rats were very ill, they continued to perform the discriminatory act without error.

PREFACE

As experience with live animals confined in blast-resistant bomb shelters during a nuclear explosion has accumulated, the necessity for regarding the total effect on an intact biological system has become apparent. It is not enough to limit the design considerations of protective shelters to such things as protection from dangerous overpressures, flying missiles, and radiant energy, although these things are important.

It is also necessary to consider those things which are conducive to fatigue and psychic trauma, such as noise, environmental temperatures, and ventilation, to name only a few. This is true because it is not enough to prevent physical trauma if the biological system emerges from the protective shelter in a state of exhaustion or in a state of profound psychological disorganization. It is not enough to minimize physical trauma if, in so doing, psychic trauma is either not equally minimized or actually worsened in the process.

In the holocaust that will result from the use of nuclear devices in warfare against civilian populations, great demands will be placed on the individuals comprising these populations. Those who have survived the initial effects of the explosions will have their ability to adapt to a radically changed environment taxed to an extreme degree. At such a time persons who are unable to care for themselves or to contribute to the care of others because their mentation is faulty, owing to fatigue or disorganization of the psyche, will be casualties. A little reflection will bring a realization that, since a casualty is an individual rendered unavailable for service because of his incapacitation, incapacitation can be as much due to a profound disruption of the neuropsychic system as to such things as wounds and fractures. A bomb shelter has only one function and that is to protect a biologic system from the traumatic forces generated by an explosion so that the number of casualties will be reduced. An ideal structure, therefore, may be considered as one which affords the maximal total protection to the biological system to which it has given shelter.

A considerable amount of experimentation has been done on animals placed in bomb shelters. This work has been directed toward ascertaining the effects of overpressures, secondary missiles, radiant energy, and other modalities capable of producing physical trauma. Much less attention has been paid in past experiments to other parameters that have their traumatic proclivities directed more toward the production of a deteriorated or disturbed psyche.

This is not to imply that the engineers and biologists who have been concerned with these experiments have been oblivious to the psychologic aspects of the general problem with which they were confronted, for such is not the case. Rather has it been that an investigation of the psychologic aspects presents a much more difficult problem because forthright experiments are difficult to conceive and carry out. There are so many variables to which a psyche is susceptible, and the observed psyche is a sort of vector sum of them all. The best that can be done is to focus attention on one modality, thought to be capable of contributing a disturbing influence, with the hope that some rough quantitative value can be derived for its contribution to the whole. By taking one after another, with good fortune, one may perhaps arrive at a more complete understanding of the problem and discover constructive measures that can be taken to minimize psychic trauma.

This study concerns itself with the role of excessive noise as a source of psychic trauma. It was selected as a suitable modality for beginning the unraveling of the whole problem because noise lends itself to precise measurement and because much has been learned about the psychologic effects of high noise levels. There is no thought among the investigators that noise presents the only disturbing influence on the psyche of animals that live through a nuclear explosion while confined in a protective shelter or even that it is of primary importance. This study is only an opening gambit. The only way such a complicated problem can be approached is to pick it to pieces, to study thoroughly each piece, and to repeat the process until each piece can be integrated with the whole.

Noise in excess of that which is compatible with human comfort has long been associated in the minds of physiologists with the fatigue syndrome. For the most part this association has been with chronic or prolonged exposure of men and animals to high noise levels. A good review of the present state of our knowledge can be found in the Benox Report, An Exploratory Study of the Biological Effects of Noise, which was assembled at the University of Chicago and sponsored by the Office of Naval Research [Report NR-144079, December 1953]. It can be seen from the data set forth in this report that prolonged exposure to noise levels in the range of 150 to 160 db is clearly etiologic in the production of the fatigue syndrome.

Much less is known about the effects on biologic systems of a single brief exposure to a noise of a greater intensity, say in the range of 190 to 200 db. There are some data presented in the Benox Report which strongly suggest that such an exposure would be traumatic both physiologically, by damage to the vestibular apparatus, and psychologically, by reduction in the capacity of the animal to perform learned complex tasks. How much of this latter is due to the production of a fatigue state is speculative.

It has been observed by C. W. Porter that a profound, but reversible, disruption of the ability to perform skilled acts results from brief exposures to intense ultrasound [C. W. Porter, Curious Effects of Ultrasound, Calif. Eng. (April 1939)]. There is reason to believe that the same thing can result from brief exposures to very intense sonic energy as well. It has been speculated that the reversible nature of this phenomenon is due to the recovery of a rapidly fatigued neurophysiological mechanism. The basic physics of sound and ultrasound are the same; the differences that exist are due to variations in frequency and intensity. Thus both can be expected to have basically similar biological actions.

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CHAPTER 1

OBJECTIVES

1.1 PRIMARY

The primary objective of this study was to utilize the opportunity afforded by the actual test of an experimental bomb shelter, under conditions predicated to give the maximum noise level generated by a nuclear explosion, to observe the effects of this noise on trained rats. By means of a surgical procedure designed to diminish the auditory acuity of part of these animals, it was hoped that the variable of noise would be singled out and made more accessible for study.

1.2 SECONDARY

A secondary objective was to study the effects of living through a nuclear explosion on the learning processes of the test animals.

CHAPTER 2

THEORY AND BACKGROUND

2.1 DESCRIPTION OF THE EXPERIMENTAL SITUATION

The circumstances surrounding the physical setup of the bomb shelters to be tested during two shots of Operation Teapot seemed to offer a good opportunity for obtaining some useful data concerning the effect of noise on the test species placed in the Federal Civil Defense Administration (FCDA) underground group shelters.

There were two shelters connected with each of these shots. They were basically of identical construction. For the details of design and construction, the reader is referred to reports[1] of Project 34.3. For the purposes germane to the noise study, it will be sufficient to state that the shelters were located close enough to the shot tower so that noise levels generated by the explosion would not be significantly attenuated by distance.

One shelter on each shot was used closed, and the main room was 12 by 25 by 8 ft. In addition, one shelter was left open and was modified for each of the two shots by placing a 1-ft concrete bulkhead inside in order to make two chambers of identical size, each being 12 by 12 by 8 ft. A heavy blast-resistant steel door closed off the bulkhead at the time of the explosion.

Heavy steel-concrete sliding doors closed off the stairway entry to the shelters. The door that had been provided for the shelter which had been divided into two parts was removed. Thus this shelter had no protective barrier interposed between the forces generated by the explosion and the front half of the shelter chamber.

The back half of this shelter had a chimneylike escape hatchway 3 ft square, for which a heavy steel hatch had been provided. This hatch was removed, and the opening at ground level was partially closed by a steel plate. In the center of this steel plate, a circular hole had been cut. The diameter of the opening was 19 in. for the first shot and 36 in. for the second shot. This modification was for the purpose of prolonging the time required for the high-pressure blast wave to increase the pressure within the back chamber. This chamber is subsequently referred to as the "slow-fill" side. As a collateral it could be shown that the chimneylike hatchway and its cover containing a hole might well act as a large whistle, or organ pipe, since the pressures generated by the blast front would cause winds at sonic velocities to pass over the orifice as the chamber became filled. Thus two noises would be generated.

The first noise would be of short duration and high intensity. The second noise would be of a longer duration and of a different pitch and intensity. These noises would be very loud, it seemed, and of a nature predicted to be traumatic.

The second shelter, on the other hand, was of a sort in which noise levels were likely to be much less intense. This was so because the large sliding door was to be secured in place prior to the detonation and the escape hatchway was to be filled with sand. Thus two sound barriers were interposed between the outside and the animals. Ventilation was provided by a special system that was installed in a room set off by a concrete partition at one end of the shelter.

2.2 PLAN OF THE EXPERIMENT

The whole situation, therefore, was such that two environments were available, one which had predictably high noise levels and one which would probably be much less noisy. This is not to imply that all the other parameters of interest would be identical in the two shelters. The animals in the closed shelter would be likely to receive much less blast, radiant energy, etc., but it was thought that an experiment could be designed to exploit the noise variable in such a manner as to give some important data. It was reasoned that, if some of the animals were deafened and the balance had normal auditory acuity, then the variable of noise intensities in the two locations would be separated to a greater degree than would the other parameters in the two locations.

It was planned to use the first shot as an exploratory experiment wherein some more definite idea of the noise levels could be obtained. However, scale settings were based on incorrect estimates of the noise level, and no useful data were obtained on this shot. Thus the experiment performed in connection with the second shot was, of a necessity, based on no more data than were available prior to the Operation Teapot series. It is well, therefore, now to consider the nature of the data available at the time these experiments were begun.

2.3 BACKGROUND

During the Operation Upshot-Knothole series of nuclear tests in the spring of 1953, a series of experiments was performed which was designed to test the protective capacity of underground shelters against the various forces generated by a nuclear explosion.[2] Dogs were used as the experimental species. Although there was no formal effort made to study the psychological effects of living through a nuclear explosion, an opportunity was presented to make some observations of certain psychological phenomena which suggested that a more deliberate scrutiny of these parameters was in order.

The dogs used in the Upshot-Knothole experiments were well-conditioned animals by the time the moment had arrived for the detonation of the nuclear device. During practice sessions, or dry runs of the experiments, it was routine for food to be withheld until the animals had been removed from the experimental shelters and returned to their kennels. After a few practice runs of the experimental situation, it was obvious that the dogs had come to associate the completion of the dry-run routine with the fact that their daily meal would soon be forthcoming. As a result, when they were brought out of the shelters, they were eager to get into the waiting trucks. Once there they assumed their places quickly. There was a noticeable difference in the behavior of the animals when they were recovered following the detonation of the test device.

In this latter case the dogs seemed to be confused and apathetic. A number had to be manhandled into the recovery vehicles. One dog ran underneath a truck and seemed to be disoriented. Another dog went to the dead end of the aisle between the animal cages, stopped, and stared stupidly at the wall.

For several days afterward the dogs were indifferent to food. Some showed a mild ataxia. As a group they appeared to have no interest in the things going on about them, whereas formerly they had barked and had become excited by everything new that had transpired in the vicinity of the kennels.

It was of some significance to the various observers to note that many of these animals had suffered little or no physical trauma. Those animals which had received wounds of one sort or another showed alterations in their behavior that were difficult to correlate with the physical trauma they had suffered. In summary, it is possible that more had happened to these animals than purely physical trauma. Perhaps there had been psychic derangement as well. These observations occasioned considerable speculation on the part of the various observers directed toward identifying the modalities by which this altered behavior could have been mediated.

There was general agreement among the observers that these dogs manifested the general clinical picture which has been called fatigue or exhaustion. Therefore speculation led into

the realm of the known causes for fatigue. Among the important of these causes are

1. Prolonged or excessive muscular work
2. Poor ventilation
3. Inadequate carbohydrate intake
4. Excessive heat and humidity
5. Anxiety or fear
6. Excessive noise
7. Radiation effects

Probably all these entered into the experimental situation under consideration; but for diverse reasons the impact of most of them could not have been too great.

The dogs were suspended in web harnesses, which were attached to the shelter ceiling by chains. When the animals were first placed in these restraints, they struggled against them. They learned, however, that struggling to escape availed them nothing; so they relaxed and let the harness support them. Many actually relaxed to the point where they would sleep. Thus the element of excessive work did not seem to be present in this experimental situation.

Considerable attention was given to the ventilation problem so that an adequate air exchange was provided for the shelters. It does not seem likely that poor ventilation was an important factor.

The dogs were in a good state of nutrition by the time the experiment was performed. They were a mongrel lot and in poor nutritional condition when they were received. All the animals gained weight to an extent that all harnesses had to be modified ultimately in order to accommodate the increased girth of the dogs. It can be safely assumed that the animals entered the experimental situation with an adequate carbohydrate reserve. This point should be checked by actual measurement of blood-sugar levels in a future experiment since it is known that the administration of glucose during an exhausting physical experience will raise the threshold for exhaustion or fatigue.[3] Carbohydrate depletion could well have been a factor in the production of the fatigue syndrome seen in these dogs.

Except for a brief time, when the temperatures within the shelters reached a maximum owing to the entrance of combusted gases, the ambient temperatures were not too extreme either one way or another. Furthermore, the dogs were conditioned to this variable, except for the momentary extreme, by the time of the actual experiment. It is unlikely that temperature-humidity conditions had much bearing.

The dogs were apprehensive when first placed in the shelters. However, after a few dry runs they became quite used to the situation, and the anxiety they had demonstrated was noticeably less by the time the moment for the detonation of the nuclear device had arrived. Undoubtedly, the experience of the actual detonation was frightening. It is difficult to equate this variable; however, this factor lends itself so poorly to measurement that it must be evaluated by the process of constituting the significant remainder after all other measurable variables have been studied.

We are left with the variable of noise to consider. One inevitably associates an explosion of anything, be it high explosive or nuclear, with the production of high-intensity noise. One reasons, therefore, that inasmuch as high-intensity noise is known to be a cause of the fatigue syndrome, it is quite possible for noise to have played an etiological role in the fatigue manifested by the animals that have been the object of this discussion.

In dosage ranges of about 900 to 1000 rep, ionizing radiation will produce symptoms closely resembling the fatigue syndrome.[4] The exposed animals will develop the characteristic signs of radiation sickness and die. Although there are some features common to both the fatigue syndrome and to radiation sickness, there are enough unique to the latter to make it safe to assert that the Operation Upshot-Knothole dogs did not manifest their symptoms because of exposure to ionizing radiation.

In summary, then, of all the known important causes of the fatigue syndrome applicable to the experimental situation of the Operation Upshot-Knothole experiments, three are left

which seem to require more deliberate study. These are

1. Carbohydrate depletion
2. Anxiety or fear
3. Noise

Since noise lends itself to measurement and since its effects can be manipulated experimentally, it was thought that an appropriate beginning could be made in the ultimate understanding of the fatigue syndrome which developed in the Operation Upshot-Knothole dogs by studying the role of noise in an experiment performed during Operation Teapot.

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CHAPTER 3

EXPERIMENTAL ANIMALS AND THEIR PREPARATION

3.1 EXPERIMENTAL PLAN

A fatigued animal appears to have difficulty in cerebration. This difficulty is manifested to an intensified degree when a fatigued animal is required to perform discriminatory acts, especially when these acts have been recently learned. It was planned, therefore, to teach a group of albino rats a discriminatory test act; that of Lashley[1] was chosen. It was further planned to make half these animals deaf by surgical means. A difference, or lack of difference, in the ability of these two groups to perform the learned act after exposure to a nuclear explosion would either establish or disestablish noise as a significant factor in the production of a fatigued state.

An attempt was made to have only the ability to hear constitute a variable in so far as possible. Since other parameters, such as blast, heat, and radiation, would have an equal impact on both the deafened and nondeafened animals, it was thought that this single variable could be kept intact.

Arrangements were made to measure the intensity of the noise by appropriate sound-measuring devices. Since this was an exploratory experiment, only intensity was measured because this could be done easily and with inexpensive instruments. If noise appeared to be of significance after the results of this study were known, then it would be appropriate to make frequency measurements as well as intensity measurements in another experiment.

Other programs and projects that were conducted in the same structures measured pressure, temperature, and radiation. The results of these measurements were available; therefore it was unnecessary to duplicate their efforts.

3.2 SURGICAL PROCEDURE FOR DEAFENING

A rat depends for its safety and survival primarily on flight instead of on combat. As is common with such animals, one finds that auditory perception is very acute and is not confined exclusively to the auditory system. Rats have been observed to respond to conditioned reflex situations when the stimulus was a precise pure tone, even when the entire auditory organs and pathways had been extirpated.[2,3-5] Thus it is virtually impossible to ensure that a rat has been rendered completely incapable of hearing.

It can be reasonably asserted, however, that a rat whose eardrums and middle-ear structures have been destroyed will hear less than will a rat whose hearing mechanism is intact and normal. To accomplish the most attenuation of audition and, at the same time, not upset the equilibration of these animals, the following procedure was used.

Under ether anesthesia each eardrum was destroyed by a high-frequency fulgurating current. Following the destruction of the tympanic membrane, the fulguration was carried into the middle ear. This was essentially a bloodless procedure and left a dry field.

After the structures of the middle ear were destroyed, the middle-ear cavity and the external auditory canal were filled with a liquid latex molding rubber preparation which solidified shortly after exposure to air. An effective rubber plug for each ear was thus obtained. In order to prevent the rubber plug from either falling out or being pulled out by the animal, a nylon suture was cast in the tragal notch at the base of the ear. When it was tied, the suture closed the external canal. Prior to tying the suture, the skin of the tragus was roughened until it bled. The effect of this was that the roughened edges were held approximated by the suture until healing had occurred. The external canal was effectively closed by sealing the two edges of the tragus by causing them to grow together and also by the nonabsorbable nylon suture.

After a little practice this entire operation was performed on both ears with the animal anesthetized for approximately 3 to 5 min. All the animals tolerated the procedure well. None developed any infection or disturbance of balance.

The only difference noted between the intact animals and those surgically deafened in their postoperative behavior concerned their responses to ambient noises, such as key jingling. Although no quantitative measurements were made, we do feel some measure of confidence in stating that, in our best judgment, the animals that had undergone the operation did not hear as well as the intact animals. This is not to suggest, however, that we thought that the animals operated upon were completely unable to hear because their activities clearly denied that such was the case. It is with some considerable degree of qualification, therefore, that we refer to the group subjected to the surgical procedure described above as the "deafened group" and the intact animals as the "nondeafened group."

3.3 SUBJECTS

All animals used in this study were male albino rats. They ranged from 120 to 150 days in age at the beginning of the experiment. Three different strains were represented: Wistar, Budd, and Sprague-Dawley. A total of 107 rats was used. Of these animals, 38 served as subjects during the first experiment, and the remaining 69 served as subjects during the second experiment.

3.4 TRAINING

After the animals were tamed, they were taught to jump through windows in a modified Lashley jumping apparatus in order to obtain food (Fig. 3.1). After the rats had learned to associate jumping with being fed, the windows of the apparatus were covered with cards (Fig. 3.2). The animals were then faced with the problem of learning which of the two stimulus cards was always unlatched. When the animal struck the unlatched card, it fell over, giving the animal access to the food behind the card (Fig. 3.3). When the animal struck the latched card, the force of the jump caused the rat to bounce off the card and fall into a plastic bag that was suspended between the jumping platform and the feeding platform.

A small white circle on a black background indicated that the window was unlocked; a small black circle on a white background indicated that the window was locked. The cards appeared in the left and right windows in a random order so that it was impossible for the animal to learn a sequence of presentations. He had to learn to respond to the positive card and to avoid the negative card. Ten trials a day were given to each animal. The learning criterion was three days of errorless trials.

3.5 EXPERIMENTAL SCHEDULE

The experimental schedule provided for some rats to learn the discrimination problem after being exposed to a nuclear detonation in order to determine what effects such a catastrophic experience had on learning. It also provided for some rats to be exposed to a nuclear detonation after having learned the problem in order to determine what effects such an experience had on the retention of a well-learned response.

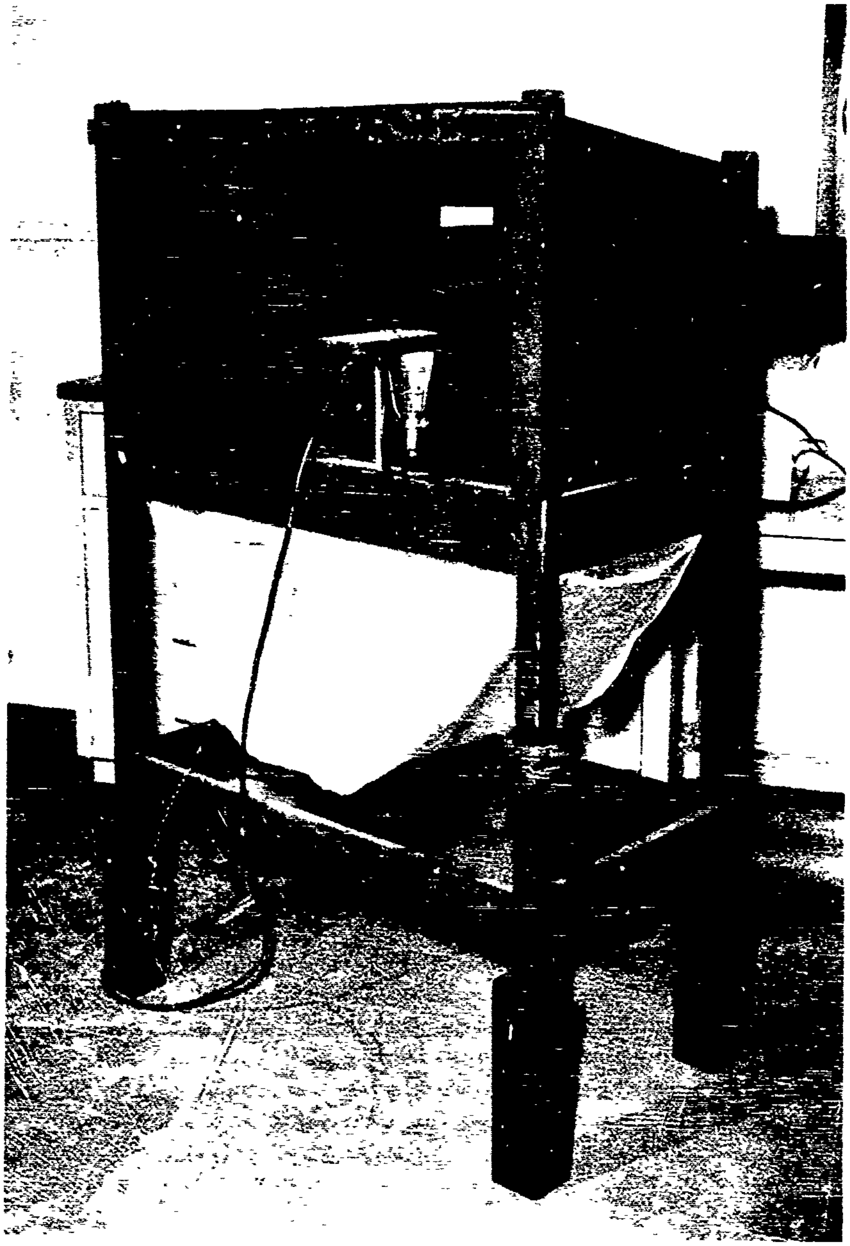

Fig. 3.1 — The Lashley apparatus.

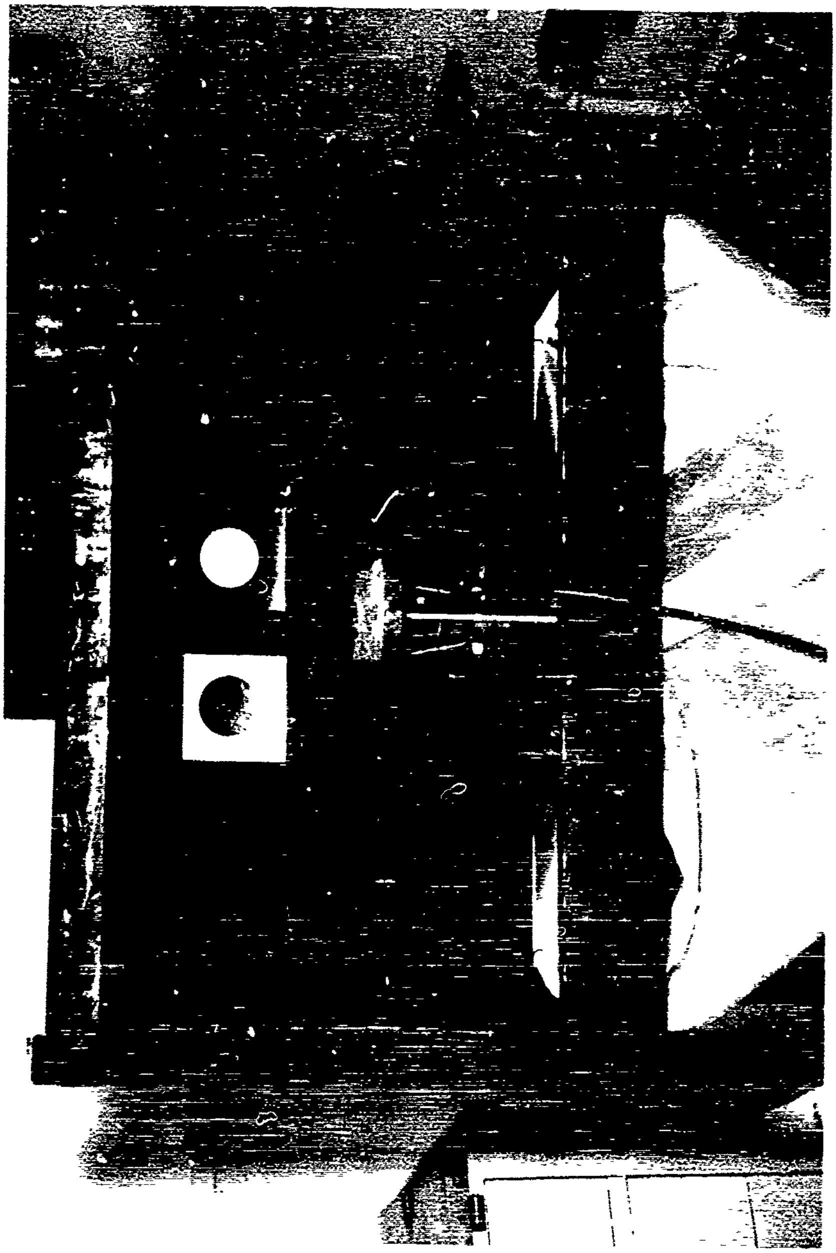

Fig. 3.2—Close-up of jumping apparatus with target cards.

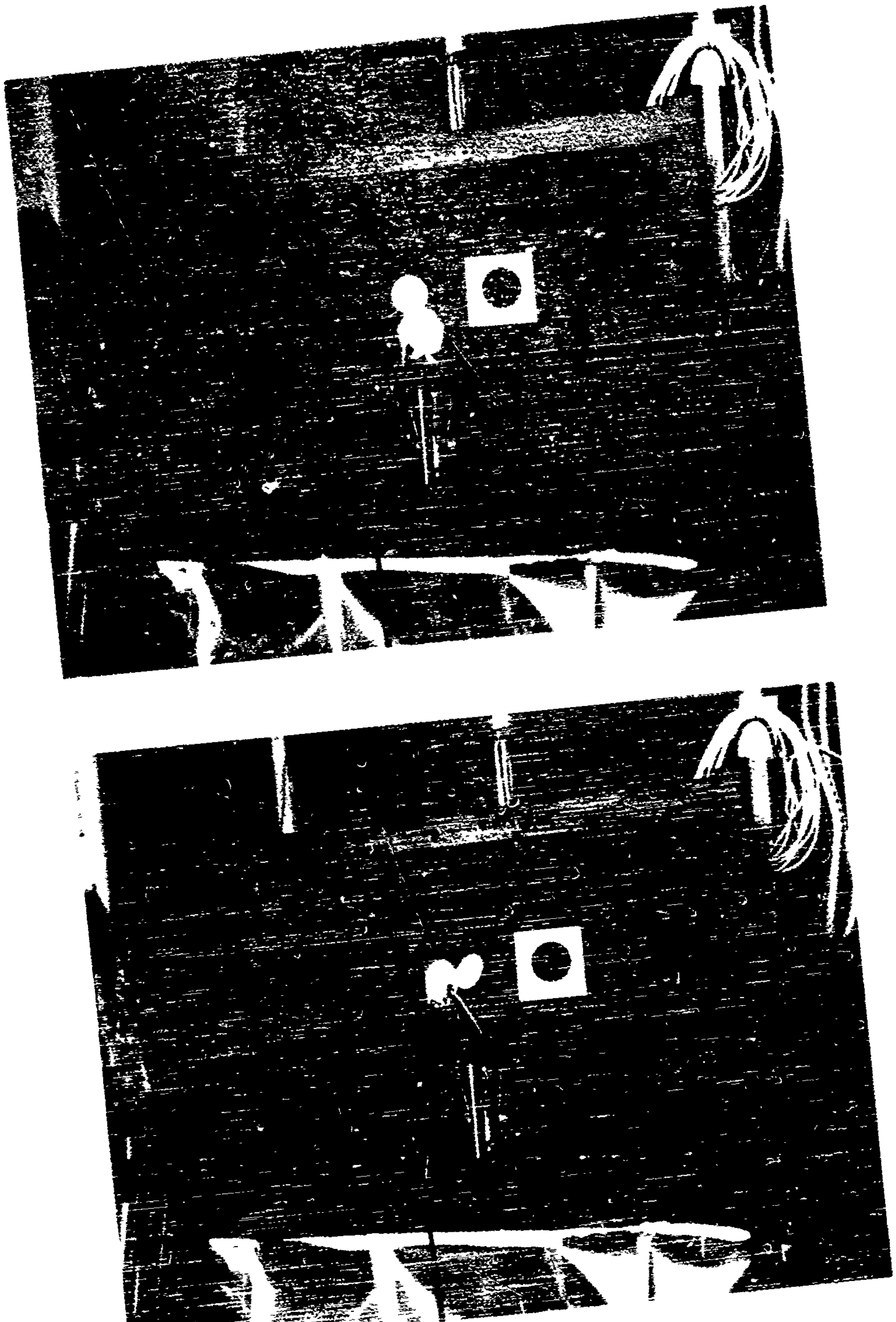

Fig. 3.3—Animals in action on jumping stand.

3.6 EFFECTS ON LEARNING

In order to test the effects of exposure on the ability to learn a simple visual discrimination problem, naive or untrained rats were used. In accordance with our purpose to test the traumatic effects of noise accompanying a nuclear detonation, some of these naive rats were deafened prior to their exposure. After the animals had been exposed, they were returned to the home laboratory where training was started. A control group of animals that had been given the same treatment, except for exposure to the shot, was also used.

This design permits a comparison of learning scores between exposed deafened vs nondeafened rats and nondeafened exposed vs unexposed rats. Differences in the ability to learn in the first instance can be attributed to differences in hearing acuity since the exposure factor is a constant. Differences in the ability to learn in the second instance can be attributed to the exposure factor since the hearing factor is a constant.

3.7 EFFECTS ON RETENTION

In order to test the effects of exposure on the ability to perform a well-learned visual discrimination response, trained rats were used. These animals had met the learning criterion of three days of errorless trials at the home laboratory. Before being shipped to the Nevada Test Site (NTS), half these animals were deafened. After their recovery they were shipped to Nevada, where they were given seven days of postlearning trials in the discrimination problem. After it was ascertained that all the animals knew the discrimination perfectly, they were divided into exposure and control groups. Furthermore, the original learning scores were used in making up the experimental and control groups so that they were equated as to fast, medium, and slow learners.

After the animals had been exposed, they were returned to the Animal House at NTS, where the postshot tests of retention were run.

3.8 QUANTITATION OF THE LEARNING PROCEDURE

The difference in the number of trials to learn and the number of trials to relearn is known as the retention score. The larger this difference, the greater is the retention; and, conversely, the smaller this difference, the greater is the forgetting. Since the mere passage of time causes some forgetting, a normal loss value can be obtained from the scores of the unexposed animals. This would be a constant for all groups. Any additional loss could, therefore, be attributed to exposure. With the exposure factor held constant (exposed deafened vs exposed nondeafened rats), any difference in retention scores could be attributed to differences in hearing acuity.

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CHAPTER 4

INSTRUMENTATION

4.1 NOISE

The maximum noise intensity reached in each of the shelters and the duration of the noise were measured. The basic instrument was a sound-level meter manufactured by the General Radio Company and designated as model GR-1551A. The microphone constituting the input to this device was a Massa M-141B. This microphone has been expressly designed by its manufacturer to stand up under extreme conditions of high-intensity noise. The output of the sound-level meter was carried by underground cable through two appropriate impedance matching transformers to a rectifier that converted the a-c signal put out by the sound-level meter to a d-c signal. This d-c signal was recorded by a photographic recording galvanometer. A schematic diagram will be found in Fig. 4.1.

All the components of the noise-recording system were shock-mounted and protected from blast, pressure, and missiles. The details of mounting are shown in Figs. 4.2 to 4.4. The high-intensity noise measuring systems were identical in both shots.

4.2 RADIATION

The shelters were instrumented for measuring the intensity of beta and gamma radiation by the use of film badges. Neutron dosimeters were deployed to measure the neutron flux on the second shot only. These were primarily of the fission-foil type.

4.3 PRESSURE

Wiancko pressure gauges were used for obtaining pressure measurements in both types of shelter.

4.4 TEMPERATURE

Temperature variations within the shelters were recorded by means of speed-of-sound temperature gauges.

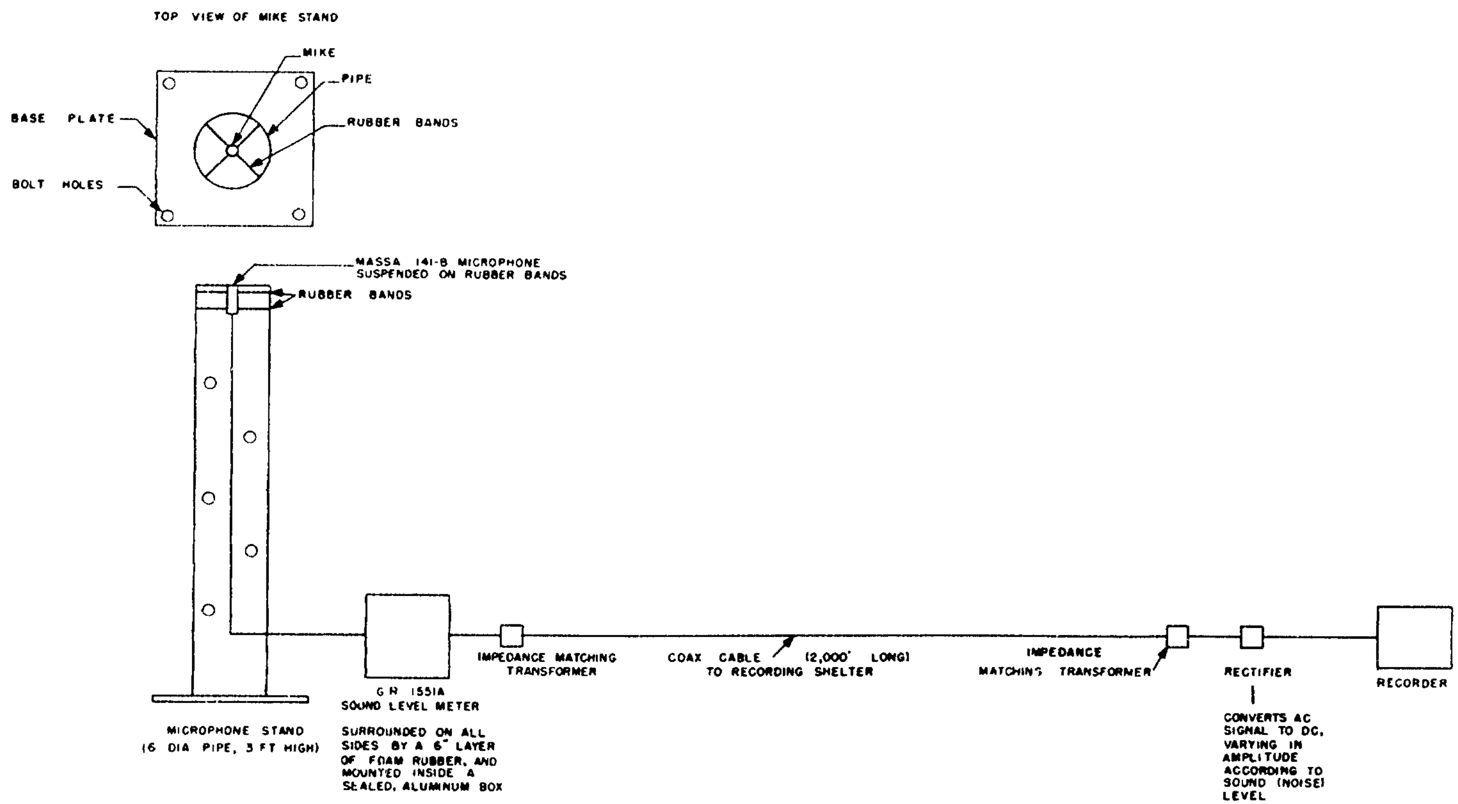

Fig. 4.1—Sound-level measurement apparatus schematic.

Fig. 4.2—Standpipe mounting for microphone and blast-resistant box housing sound-level meter.

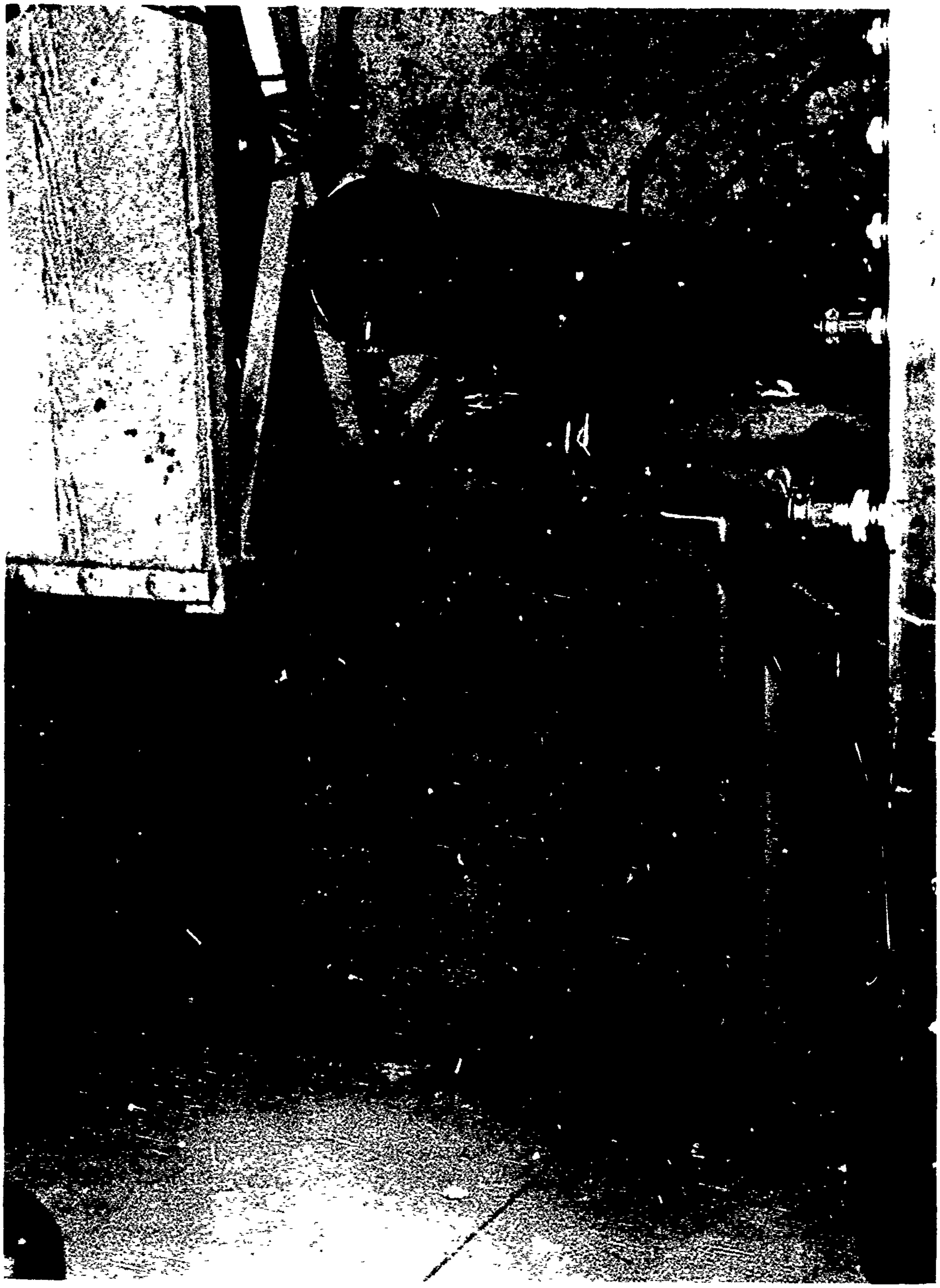

Fig. 4.3—Top view of standpipe mounting for the microphone.

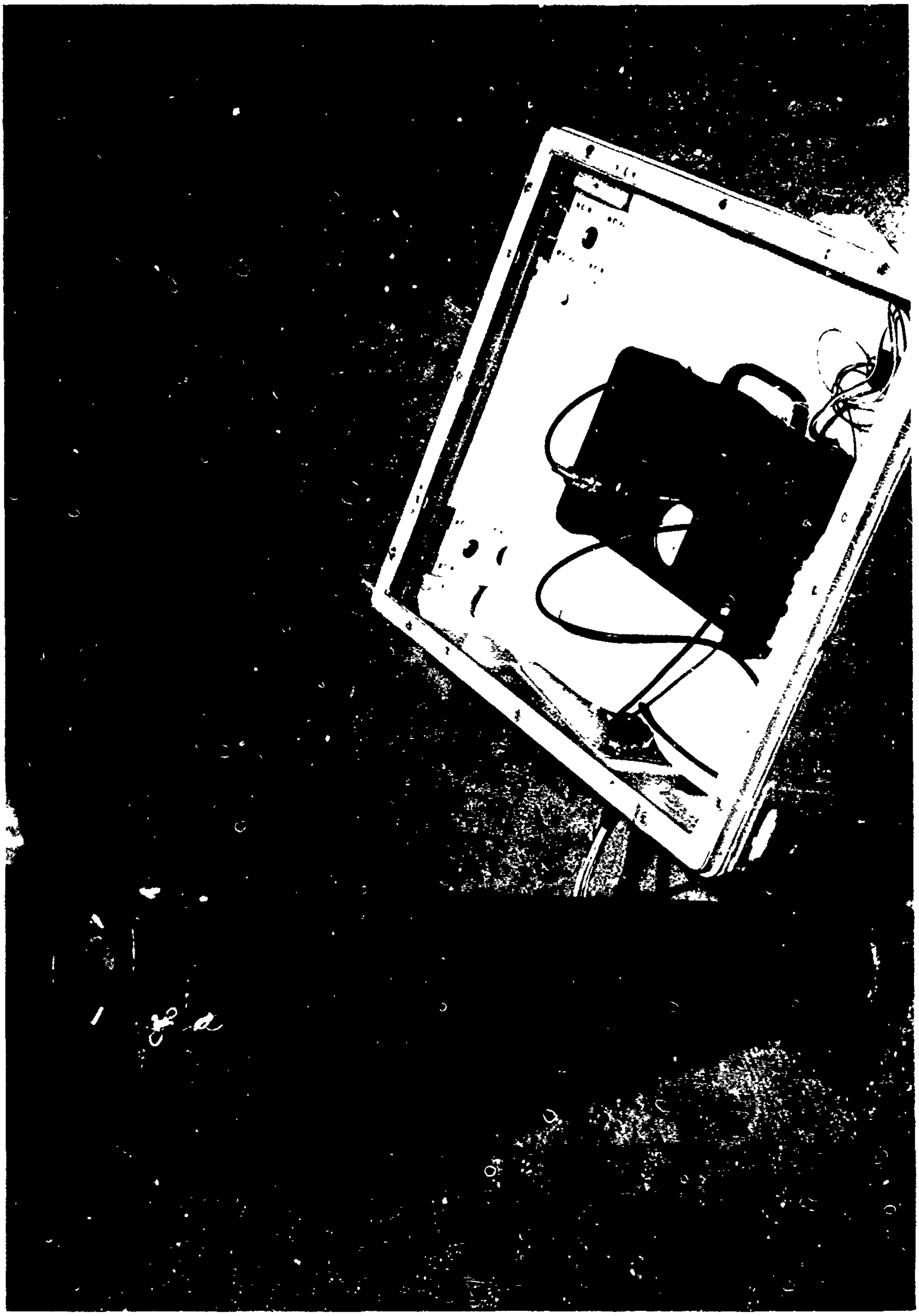

Fig. 4.4—Blast-resistant box containing sound-level meter, showing method of padding.

CHAPTER 5

OPERATIONS

5.1 PLACEMENT

The animals that were placed in the slow-fill side of the open shelter were distributed five to a cage, except for the naive group which consisted of one cage containing seven rats. The cages were placed on top of a bench located in the center of the room. They were tied down by a length of twisted steel cable, secured at each end by cable clamps. This type of placement was identical on both shots.

On the first shot the cages in the closed shelter were placed on top of the box housing the sound-level meter, which was located in the center of the shelter. The cages were held in place by a steel cable strap, which had stiff springs and harness snaps on each end. The harness snaps clipped onto the box handles, and the spring tension held the cages firmly in place.

The placement of the animals on the first shot was simple since only naive animals were used. They were divided into two groups of 9 animals and one group of 20 animals. One group of 9 was placed in the open shelter, the other group of 9 was placed in the closed shelter, and the remaining 20 animals served as the unexposed controls.

On the second shot the cages in the closed shelter were placed on a hair-mat pad, which was placed on the floor. A steel cable with springs and harness snaps was run across the top of the cages. The harness snaps clipped into two steel rings that were fastened to the floor by bolts set into the concrete.

The test animals for the second shot were divided into three groups. Each group contained representatives of the deafened trained animals; the nondeafened trained animals; and the naive, or untrained, animals. Groups A and B were placed in the shelters; group C remained in the laboratory.

Owing to the method used to prepare the closed shelter for the experiment, it was necessary to leave the animals in it overnight when the shot was postponed. The animals in the open shelter, on the other hand, could be brought back to the laboratory. Therefore, as a precaution against exposing the members of either group A or group B to more environmental hazard than the other, they were alternated between the open and closed shelters each time the shot was scheduled. Owing to the frequent postponements each group spent several nights in the closed shelter.

The results were that group A was in the open shelter at the time of the actual detonation, and group B was in the closed shelter. Table 5.1 shows the distribution of animals for the second shot.

Table 5.1 — PLACEMENT OF ANIMALS

Group	Animal No.		
	Deafened	Nondeafened	Naive
A, open shelter	203, 201, 9, 50, 19, 199, 206, 32, 221, 7	202, 204, 213, 219, 40, 22, 30, 51, 200	223, 226, 229, 232, 235, 238, 240
	Total 10	Total 9	Total 7
B, closed shelter	220, 216, 3, 65, 12, 47, 205, 44, 59, 56	215, 212, 102, 92, 73, 11, 45, 98, 218	224, 227, 241, 230, 233, 236, 239
	Total 10	Total 9	Total 7
C, remained in laboratory	58, 217, 222, 91, 211	209, 208, 16, 214, 94, 2	225, 228, 231, 234, 237, 242
	Total 5	Total 6	Total 6

5.2 RECOVERY

The recovery of the animals was effected approximately 10 hr after each detonation. The cages containing the animals were brought back to the laboratory, where an exchange to clean cages was made. The contaminated cages were washed off and were found free of contamination after the washing.

No unusual difficulties were encountered in effecting the recovery of the animals. It was simply a question of waiting until the radiation levels had reached a low enough point to permit access to the shelters.

CHAPTER 6

RESULTS

6.1 FIRST SHOT

It can be said at the outset that the parameter of noise was not found to be of significance. There was no observed difference in the ability of the deafened and nondeafened groups to learn the discrimination test.

An inherent defect in all commercially available sound-level measuring devices is the restricted range of the galvanometers used to measure the voltage generated by the transducer. All such instruments are furnished with a galvanometer whose range is only about ±30 db with the instrument set on any range of sensitivity. It is necessary, therefore, to set the sensitivity range at some estimated point. If one has over- or underestimated the intensity, one has to select a more appropriate scale. Although this presents no problem ordinarily, it posed a real one in this case. Since no change could be made in scale settings, it was necessary to guess in advance, to within ±30 db, what noise levels would be encountered when the nuclear device was detonated. Unfortunately, an incorrect estimate was made, and no records were obtained from this shot.

All the animals placed in the shelters were untrained. When recovered from the shelters, all the animals presented a normal appearance, except that the rats from the open shelter were covered with dust. They ate, took water, and engaged in grooming activities. They were taken to the home laboratory via automobile, a trip of 600 miles, which required two days. The animals subsisted on raw potatoes during the trip. It was noticed that most of the potatoes remained uneaten, which signified a diminished appetite.

This lack of appetite persisted, except for the control animals. The unexposed animals ate normally, whereas the rats that had been exposed began to lose weight and to become apathetic. By the time two weeks had elapsed after exposure, it was obvious that all exposed animals had radiation sickness.

The first death among the exposed animals occurred two weeks after exposure, and in the week that followed a total of six rats died. On autopsy the characteristic lesions of radiation sickness were found.

By the time four weeks had elapsed following exposure, the remaining exposed animals manifested recovery from the radiation sickness. Their appetite returned, they became more active, and their body weights increased. It was found, however, that all the exposed animals had difficulty meeting the learning criterion for the discrimination test, whereas the control animals showed a normal capacity to learn.

It is also of interest to note that two of the exposed animals developed lesions of the eyes which looked like incipient radiation cataracts.

There was no difference in the degree of inability of those animals in the closed shelter to learn as compared with those in the open shelter. All exposed animals failed to meet the learning criterion for the discrimination test, even after apparent recovery from radiation sickness. They had developed strong position responses; i.e., they jumped consistently to the

left or right windows regardless of the position of the negative and positive cards. Frequently they jumped short of the target windows, but even the short jumping was directed to the preferred side of the apparatus. The rats, however, showed definite signs of learning because they jumped immediately when the positive card was in position on the preferred side, whereas much prodding was necessary when the negative card was in position on the preferred side.

In summary, then, all the animals exposed during the first shot developed radiation sickness. Although the animals learned the discrimination problem, they were unable to express this learning because of strong interfering position responses. No difference was observed between the deafened and the nondeafened rats. The control animals did not develop radiation sickness, and they all learned the discrimination problem in a normal way.

6.2 SECOND SHOT

The measured noise intensity in the slow-fill side of the open shelter was 181 db. The duration of this peak was 35 msec. The anticipated whistle effect of the escape hatch and its round orifice did not materialize.

Measured noise intensity in the closed shelter was 173.0 db. The duration of this peak was 128 msec.

Measured overpressure in the slow-fill chamber of the open shelter was 37 psi, in contrast to no measured overpressure in the closed shelter.

Although a high air temperature flux (340 to 360°C) was measured in the slow-fill side of the open shelter, its duration was too brief to account for the type of burns sustained by the rats placed there.* The severity and the distribution of the burns were not uniform among the subjects, but all the rats were burned to some degree. Characteristics common to the entire group were a singed appearance of one or more delineated areas of the pelts, a singed and wilted look to the vibrissae, and a blistering around the outer edges of the ears. Several animals had badly burned eyes and noses, and some had blistered feet. The animal pictured in Fig. 6.1 shows the type of pelt burn that was encountered. The hair is badly singed in one area, whereas the hair immediately above it is hardly damaged. In addition, the skin underlying the singed hair did not appear burned. Figures 6.2 and 6.3 show the type of burns that occurred to the eyes, noses, ears, and feet of the subjects. In the ninth column of Tables 6.1 and 6.2, we have indicated the severity of the burns sustained by the rats.† Actually, only three animals sustained third-degree burns, and these cases are indicated in the footnotes.

Although we are unable to determine the actual factors, e.g., burning particles or dust, responsible for the injuries that were noted when the animals were first recovered from the open shelter, it is thought that, because of their characteristics and variant distribution among the rats, these burns were contact burns and were not the result of radiant energy.

The animals from the open shelter appeared fatigued when recovered. They showed little interest in food and drink. The animals from the closed shelter, by contrast, appeared normal in all respects. They were alert, thirsty, and hungry. All rats were made to perform the discrimination test, beginning with the first animal 14 hr after exposure and concluding with the last exposed animal 19 hr after exposure.

The detailed records of the postexposure jump tests are tabulated in Tables 6.1 to 6.3.

It is immediately apparent from these results that the noise derived from the detonation of the device under consideration is of no significance in so far as altering the ability of these animals to perform the discrimination test. No differences in retention were found to exist between the deafened and nondeafened animals, the open shelter and the closed shelter groups, nor the exposed and unexposed groups.

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*The temperature gauges were located on the wall behind the animals and opposite the open hatch. A temperature gradient existed in the chamber; consequently the animals were actually exposed to higher temperatures than those recorded by the gauges.

†The grading of the burns indicates the extent of burned pelt and not the degree of burning as is the method used by the clinician or pathologist.

Fig. 6.1—Type of pelt burn sustained by animals.

Fig. 6.2—Type of burns sustained by animals eyes, nose, ears, and feet.

Fig. 6.3—Close-up of eye, nose, and feet burns.

Table 6.1—COMPARISON OF LAST TEN PRESHOT TRIALS VS FIRST TEN POSTSHOT TRIALS OF ANIMÁLS IN CLOSED SHELTER

Rat No.*	Cage No.	No. hours tested after shot	Av. No. of seconds to jump		Retention score, %	Condition of animal†		
			Preshot	Postshot		Fatigue	Hunger	Burns
213 ND	1	15.0	7.0	3.9	100	0	xxx	0
219 ND	1	15.1	18.0	12.7	100	0	xxx	0
204 ND	1	15.2	6.7	9.3	100	0	xxx	0
51 ND	1	15.3	16.4	11.1	100	0	xxx	0
94 ND	1	15.5	10.5	9.9	100	0	xx	0
202 ND	3	15.6	10.9	19.8	100	0	xxx	0
40 ND	3	15.8	3.2	5.0	100	0	xxx	0
22 ND	3	15.9	17.6	13.4	100	0	xxx	0
200 ND	3	16.0	4.7	3.7	100	0	xxx	0
65 D	2	17.5	6.4	3.1	100	0	xxx	0
12 D	2	17.6	3.9	3.5	100	0	xxx	0
205 D	2	17.7	6.2	7.4	100	0	xxx	0
216 D	2	17.8	5.7	4.7	100	0	xxx	0
59 D	2	17.9	6.2	2.9	100	0	xxx	0
220 D	4	18.0	5.3	8.0	100	0	xxx	0
44 D	4	18.1	4.5	4.4	100	0	xxx	0
47 D	4	18.2	4.5	8.5	100	0	xxx	0
56 D	4	18.3	4.6	5.5	100	0	xx	0
3 D	4	18.4	12.4	9.1	100	0	xxx	0

*ND after the rate number indicates a nondeafened animal; D after the rate number indicates a deafened animal.

†xxx, severe; xx, moderate; 0, not apparent.

Table 6.2—COMPARISON OF LAST TEN PRESHOT TRIALS VS FIRST TEN POSTSHOT TRIALS OF ANIMALS IN OPEN SHELTER

Rat No.*	Cage No.	No. hours tested after shot	Av. No. of seconds to jump		Retention score, %	Condition of animal†		
			Preshot	Postshot		Fatigue	Hunger	Burns
11 ND	2	18.5	10.2	9.3	100	xxx	0	x
102 ND	2	14.0	10.4	12.0	100	xx	x	x
212 ND	2	14.2	6.1	6.3	100	xxx	0	x
92 ND	2	14.3	9.6	6.5	100	xx	x	x
98 ND	3	14.4	18.3	14.6	100	x	xx	xx
73 ND‡	3	14.5	7.4	5.9		x	xx	x
215 ND	3	14.6	5.6	5.2	100	x	xx	xx
45 ND	3	14.7	18.4	13.6	100	x	xx	x
218 ND§	3	14.9	4.5	3.4	100	x	xx	x
7 D¶	4	16.5	15.3	32.1	100	x	x	xxx
32 D	4	16.8	3.1	11.1	100	x	xxx	xxx
206 D**	4	16.9	11.4	16.7	100	x	xx	xxx
221 D	4	16.3	21.2	21.3	100	x	xx	xx
199 D	4	16.0	3.3	4.2	100	0	xxx	xx
50 D	5	17.0	5.0	20.8	100	x	xx	xxx
9 D	5	17.2	2.9	6.6	100	x	xx	xxx
19 D	5	17.3	11.3	14.3	100	x	xx	xxx
201 D	5	17.5	5.0	10.7	100	x	xx	xxx
203 D††	5	53.0	7.3	9.2	100	xxx	xxx	xxx

*ND after the rate number indicates a nondeafened animal; D after the rate number indicates a deafened animal.

†xxx, severe, xx, moderate; x, slight; 0, not apparent.

‡Did not jump to cards; kept hitting high to the left of the cards with side of body. Had similar experience with this animal during the preshot test trials; however, he was performing perfectly on the last preshot tests.

§Left eye injured.

¶Nose severely burned.

**Nose and eye severely burned.

††Animal escaped from cage during recovery; remained in shelter for 34 hr until second recovery party retrieved him.

Table 6.3—COMPARISON OF LAST TEN PRESHOT TRIALS VS FIRST TEN POSTSHOT TRIALS OF UNEXPOSED CONTROL ANIMALS

Rat No.*	No. hours tested after shot	Av. No. of seconds to jump		Retention score, %
		Preshot	Postshot	
2 ND	19.0	15.9	11.1	100
214 ND	19.1	4.3	4.0	100
30 ND	19.2	5.6	9.0	100
16 ND	19.3	4.5	3.8	100
209 ND	19.4	3.3	3.2	100
208 ND	19.5	3.8	3.5	100
58 D	19.6	9.0	6.1	100
211 D	19.7	5.0	3.9	100
91 D	19.8	2.7	3.0	100
222 D	19.9	5.6	6.0	100
217 D	20.0	3.4	20.4	100

*ND after the rate number indicates a nondeafened animal; D after the rate number indicates a deafened animal.

A marked difference was noted in the manner of jumping of the injured rats from the open shelter when their preexposure and postexposure performances were compared. The post-exposure jumping was so soft and easy that the force of the impact of the animal's body against the unlocked card was barely sufficient to cause the card to fall over. It was quite evident from their behavior that jumping caused considerable pain. It is remarkable that under these circumstances the animals performed at all, especially since no forcing was used to induce responses and so little interest was shown in the food used as the reward for jumping.

Since all but one of the animals showed 100 per cent retention, it was possible to return them by plane to the home laboratory the day after exposure. At the laboratory the naive animals were trained, and continued observations were made on the trained groups.

After the animals had been back in the home laboratory for four days (fourth day after exposure), those that had been exposed in the slow-fill side of the open shelter began to sicken and die. All the naive animals from this group were dead by the seventh postexposure day. Thus the results of the effects on learning of the detonation experience were limited to those naive animals that had been housed in the closed shelter.

These animals showed no differences, qualitatively or quantitatively, in their ability to learn the discrimination. When the learning scores of the naive rats from the closed shelter are compared with the scores of the naive controls and with the original learning scores of the trained group, no significant differences are found (Table 6.4). The average number of trials to learn for the first group was 112.9, as compared with 113.3 and 109.4 for the other two groups, respectively.

Thus it would appear from the results that the closed shelter, in this instance, afforded complete protection from all environmental hazards that might alter the discriminative learning ability of rats.

The deaths of those animals exposed in the slow-fill side were all resultant from ionizing radiation. Table 6.5 shows the location, weight changes, and survival times for each of the animals.

It should be emphasized that such thermal burns as the animals suffered were without influence on the survival time. Animals from cages 4 and 5 received more burns than did those in cages 1 and 2, but it was the latter group that succumbed the earliest. (See Table 6.6 for pathologic data of interest.)

The most deaths occurred on the seventh day following exposure. There were two animals which survived for longer periods of time, namely, 66 days and 111 days. The median survival time was calculated at eight days. Thus the dose in roentgens equivalent physical appears from this biological end point to be between 1000 and 1100 rep.

The clinical syndrome manifested by these animals was typical of that associated with radiation sickness; and the histologic picture of the tissues of these animals was also entirely compatible with death due to ionizing radiation.

It is of some interest to note that the two animals that lived the longest were very ill, but they appeared to recover somewhat after the fourteenth day. When they died, however, it was following a symptom train closely approximating that manifested by them shortly after exposure, and their tissues showed typical radiation changes. Thus these animals ultimately died of the radiation they had received, along with their cage mates, at the time of detonation. It is of interest to speculate on the reasons for the longer period of survival in these two animals. One of these animals was manifestly unstable from a psychological point of view. What relation, if any, this instability may have had to this radioresistance is unknown. Here might be a lead that is worth following by some future deliberate and definitive experimentation.

Only one animal that had been placed in the closed shelter died following exposure. On autopsy this animal had an acute suppurative pleuritis and pericarditis. It is unlikely that the death of this animal can be attributed to radiation. It is of interest to note, however, that this animal had bilateral lenticular opacities that had all the characteristics of radiation cataracts. These were posterior subcapsular lesions in a moderately advanced state of opacification. The lesions had developed within 11 days after exposure, which is much too short a time for the development of neutron cataracts. Lesions like this can be produced within

Table 6.4—LEARNING SCORES

Group	No. of animals	Range of No. of trials to learn	Av. No. of trials to learn
Naive (closed shelter)	7	80-130	112.9
Naive (controls)	6	100-140	113.3
Trained*	49	30-190	109.4

* The original learning scores of the animals that were used in the retention tests.

Table 6.5—SURVIVAL TIME OF ANIMALS FROM OPEN SHELTER

Rat No.*	Cage No.	Weight, g		Survival time, days
		Preexposure	At death	
223 ND	1	333	254	4
238 ND	1	292	213	4
212 ND	2	279	199	5
11 ND	2	288	201	5
235 ND	1	329	230	5
102 ND	2	224	153	6
229 ND	1	317	229	6
240 ND	1	308	225	6
92 ND	2	279	212	7
226 ND	1	300	205	7
232 ND	1	291	205	7
215 ND	3	311	192	7
206 D	4	286	192	7
7 D	4	281	179	8
221 D	4	223	160	8
203 D	5	283	187	8
98 ND	3	225	136	9
9 D	5	272	190	9
50 D	5	328	262	11
201 D	5	289	193	11
65 D†	II	259	188	11
199 D	4	358	206	12
19 D	5	269	213	12
32 D	4	200	148	12
218 ND	3	385	210	13
45 ND	3	303	203	66
73 ND	3	294	218	111
			Median survival time	8

* ND after the rate number indicates a nondeafened animal; D after the rate number indicates a deafened animal.

† 65 D was the only death in the group of animals housed in the closed shelter.

this time period by electromagnetic radiations in the microwave portion of the spectrum. Therefore one wonders if these cataracts were not resultant from microwave radiation rather than from neutrons. On the basis of this one case, a decision cannot be reached. One would like to know the intensity of the radio-frequency flux and its duration timewise. If a flux of several hundred watts per square centimeter went through the shelter, it could have produced acute cataracts, even though its duration was very brief. On the other hand, if a significant flux was present, more than one animal should have developed lenticular lesions. Although there is no readily acceptable explanation for the presence of cataracts in this animal, nevertheless they existed.

Table 6.6—PATHOLOGIC FINDINCS

Animal No.	Cage No.	Death (postexposure), days	Pathologic changes*								Other changes
			Heart	Lung congestion	Lung edema	Lung focal hemorrhage	Chronic bronchitis	Granulocytic leukopenia	Patchy atelectasis	Focal emphysema	
223	1	5									
238	1	5									
11	2	6									
212	2	6									
235	1	6									
102	2	7	–	+	++	++		+		+	
229	1	7	0	+++				+	+	+	
240	1	7	–	+			+	+		–	
92	2	8	0	++	+	+		+		+	
226	1	8	0	±			+	+		+	
232	1	8	0	+			+	+		+	
215	3	8	–	±				+		–	Thickened bronchial arteries; lung large
206	4	8	–	+	+	+	++	+	+	+	Caseo-necrotic granuloma; lung large
7	4	9	–	++	?	?	++	+	+	+	Autolysis
221	4	9	0	++			+	+	+	+	
203	5	9	0	–	–	–	+	?	–	–	
98	3	10	0	+	+	+	++	–		–	
9	5	10	0	+			++	–			Interstitial pneumonitis; multiple granulomas in lung
50	5	12	–	++			+	+		+	Autolysis
201	5	12	0	+	+	+	+	+			
199	4	13	0				+	+			
19	5	13	–		+	+	+++	–		+	Acute bronchitis, pneumonitis
32	4	13	0				+++	–			Acute suppurative bronchitis
218	3	14	0		+	+	+	+		–	
45	3	66	–	+++	?	?	–	–	–	+	Liver; extreme sinus stasis and congestion; tissues autolyzed; acute inflammation pericardium
73	3	111	–	+++	?	?	++	–		+	Caseo-necrotic granulomas in lung, autolysis, focal penumonia spleen; atrophy malpighian follicles; hepatic vascular stasis
65†		12	–					–		–	Acute suppurative pleuritis and pericarditis

* +++, marked change, ++, moderate change, +, definite change, ±, slight change; –, negative; and 0, no specimen.
† Closed shelter.

CHAPTER 7

DISCUSSION

In summarizing the causes of the fatigue shown by the dogs in the Operation Upshot-Knothole experiments, we called attention to three possibilities: carbohydrate depletion, anxiety or fear, and noise. It would appear from our results that the answer to the fatigue problem must lie in investigating the roles of carbohydrate depletion and anxiety or fear, for noise, per se, did not contribute to the fatigue shown by the animals in the present study. Actually, the results of the two studies differ quite markedly in the postexposure behavior of the experimental subject. The psychic derangement shown by the dogs certainly was not manifested by any of the rats. It is true that the rats did show some measure of fatigue upon recovery, but this fatigue was found to have no effect on their postexposure discrimination-retention performance. Thus in the present study it appears that noise was not found to be of significance in causing fatigue, and fatigue was not found to be of significance in causing any psychic derangement.

It is of the utmost importance to emphasize the fact that, although the naive animals exposed during the first shot did not meet the learning criterion for the discrimination problem, they did learn the discrimination. The type of behavior they displayed in the learning situation is that which Maier[1] terms "abnormal fixations." An abnormal fixation is a compulsion to continue a kind of activity that has no adaptive value. In this case the act of jumping consistently to one window, regardless of the card in place, may be regarded as a compulsive act. The rat does it despite the fact that it knows that, when the negative card is in the window, it will bang its head and fall into the net below. Because of the compulsive character of such behavior, its replacement by a more adaptive response is prevented (in this instance, jumping to the other window).

Abnormal fixations are produced by frustrating situations. If the learning conditions for these animals are examined, the appearance of this behavior becomes understandable. Training on the jumping stand was started soon after the animals had been exposed. The procedure provided for food to be used as the reward for the correct response and a banged nose and a fall to be used as the punishment for the incorrect response. Tapping the rat on the tail with a pencil when it did not jump within 30 sec was used as the forcing agent. Since the animals were not motivated by the food, they were reluctant to jump. When they delayed jumping, they were punished (by tapping their tails). Thus the animals were placed in a conflict situation — they had a choice between two negatively toned alternatives: jumping, which they did not care to do, or remaining on the jumping stand which led to being tapped on the tail, a highly irritating experience. Under these conditions the problem situation became one that eventually led to frustration, and the behavior elicited showed all the classic signs thereof. As experience in the situation continued, the rats began to associate the positive card with an unlatched window, but the compulsive aspect of their fixations prevented them from jumping to the positive card when it did not appear on the side of their position preference. However, they did display a differential response to the positive and negative cards. This was shown by the degree of resistance to the cards and the frequency of abortive jumps (jumps toward the card which are

inadequate for gaining entrance to food). In other words, when the negative card appeared on the fixated side, the animals took much longer to respond, and, when they did respond, they jumped so that they struck the locked window with the side of the body, permitting them to fall feet first into the net below. When the positive card appeared on the fixated side, significantly less time was taken to elicit a response, and the animals jumped straight through the window. Thus the animals made the required differentiation but were unable to practice the required response.

When none of the rats had abandoned their position stereotypes in 200 trials, guidance therapy was introduced. The method of guidance leads the animals through an alternate response — in this case, manually guiding them to choose the positive card, regardless of the window in which it appears. From five to ten trials of guidance completely eliminated the position fixations in these animals, further evidence that learning had already taken place since no rat can learn this discrimination in so short a time.

The results of this part of the experiment point up the importance of providing adequate positive motivation when survivors of a nuclear explosion are to be trained. In this instance we were dealing with laboratory rats, relatively uncomplicated organisms that did not carry over into the experimental situation the psychological trauma caused by intense fear, grief, horror, and the like. Providing adequate positive motivation will be a task of gigantic proportions. The quality of behavior elicited is a function of the situation as the subject views it. Goals or rewards selected by another party may not be the goals or rewards for which a subject will work. One may ask what rewards would be adequate for a man who witnessed the destruction of his family, friends, and belongings. The effects of such a horrendous experience could render such an individual useless, despite the fact that he may have suffered little physical injury. The use of fear as a driving or forcing agent to make survivors conform to a new routine may result in further havoc — the fixing of unadaptive behavior patterns, patterns that can further endanger the individual and even the group. However, if a knowledge of the dangers of punishment (i.e., fear of the consequences) is known, care may be taken to avoid further frustrating the individuals in question.

The significant finding of the second part of the present study is that no alteration in retention occurred in the exposed animals. This is in line with the results of several studies[2,3] that have reported the effects of X radiation on the behavior of monkeys. Monkeys irradiated at the levels used for these studies showed no deterioration in their ability to solve complex learning problems nor any decrease in the accuracy of performance of already learned acts. This was found to be true even with animals on the verge of death.

In the present study the animals that were housed in the open shelter not only received lethal doses of radiation but were also exposed to the other environmental hazards that accompany a nuclear detonation. When the animals were returned to the laboratory, they were not interested in food, and jumping, in their burned condition, was obviously a painful experience. In spite of this, when these animals were placed on the jumping stand, no forcing was needed to elicit a response. The complete familiarity of the situation called forth the adequate behavior — familiarity that had been gained through very extensive and intensive training.

It is difficult to ascertain what motivation sufficient to elicit the appropriate response was present in this case. Since no forcing was used, the animals could have resisted jumping. The interest in the food reward was certainly lacking. The animals jumped through the appropriate windows and just waited on the feeding platform (without eating) to be picked up and put on the jumping platform again. Since they were not jumping to the food or jumping away from punishment, some other motivating conditions must have been functioning. This raises the interesting possibility that complete familiarity with a situation as a function of overlearning may be sufficient to elicit appropriate behavior, despite the fact that the classical negative and positive goals are absent. This matter certainly deserves further investigation.

It is unfortunate that the naive animals from the open shelter died before any learning scores could be obtained. However, the scores of the animals from the closed shelter offer evidence that, given adequate protection during a nuclear explosion (and the closed shelter did give such protection), these animals will learn as readily as unexposed animals.

The main contribution of this study to civil defense planning is to be found in the demonstrated importance of thorough training, even when protection during a nuclear detonation is inadequate.

REFERENCES

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2. L. E. Moon, H. F. Harlow, and G. P. Bogumill, Some Effects of Periodic X Radiation, Science, 122: 863-864 (1955).
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CHAPTER 8

CONCLUSIONS

8.1 NOISE

It appears that, even though quite high noise intensities are experienced by animals in bomb shelters, the duration of the noise is so short that it has very little effect on the organism. We conclude that noise per se is not a parameter of importance in bomb-shelter design considerations.

8.2 LEARNING AND RETENTION

It appears that animals which have been thoroughly trained will not have the results of such training disturbed by the experience of living through a nuclear explosion while housed in adequate or inadequate (at least within the limits of this study's design) bomb shelters.

On the other hand, it appears that animals which have not been trained will have difficulty in learning new things unless they are housed in adequate bomb shelters.

8.3 FATIGUE

Fatigue is experienced by animals exposed to nuclear explosions in bomb shelters. If restraint, noise, blast, and high-temperature fluxes are reduced to a minimum (open shelter vs closed shelter results), fatigue will be less intense. The problem surrounding the elimination of fatigue under these circumstances remains to be more completely studied.

8.4 RADIATION

Once again it has been demonstrated that radiation within the limits of this experiment has no effect on the ability of animals to perform learned discriminatory activities.

CHAPTER 9

RECOMMENDATIONS

9.1 FATIGUE

It is recommended that studies be continued at future experiments in the field to explore more fully the problem of fatigue. These studies should employ a trained group of animals of a single strain and species whose behavior patterns are known. Biochemical studies concerned with carbohydrate metabolism should be included. Preferably, such experiments should not be incorporated into a program that requires modification of the structure in a direction which diminishes its protective features.

There is evidence that people might be required to subsist in bomb shelters for some periods of time after an explosion. A well-trained experimental species that is caused to simulate the actual operational experience of a theoretical group of people might well give data of significance in civil defense planning.

9.2 RADIATION

The neutron flux inside shelters should be more completely and precisely measured as opportunities present themselves on later tests. The attenuation of the neutron flux and its qualitative alteration should receive attention.

It is also suggested that some more attention be paid to the electromagnetic transient accompanying a nuclear explosion so that its biologic implications can be considered.

The relation between stress and radiosensitivity has received much attention by other workers.[1] It would be of interest, however, to consider the case of the chronically stressed animal, i.e., a psychologically disturbed one, more fully. Such an investigation would be primarily a laboratory study and not a field study, except perhaps as a final experiment.

REFERENCE

1. Z. M. Bacq and Peter Alexander, "Fundamentals of Radiobiology," Academic Press, Inc., New York, 1955.